

BIOLOGICAL INTEGRITY OF SOUTH COTTONWOOD CREEK AND THE LOWER GALLATIN RIVER BASED ON THE STRUCTURE AND COMPOSITION OF THE BENTHIC ALGAE COMMUNITY

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February 21, 2003

Summary

In September 2002, 9 periphyton samples were collected from 6 sites on the lower Gallatin River and 3 sites on South Cottonwood Creek near Bozeman, Montana for the purpose of assessing whether these streams are water-quality limited and in need of TMDLs. The samples were collected following MDEQ standard operating procedures, processed and analyzed using standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

Diatom metrics indicated minor impairment from sedimentation at all sites on the lower Gallatin River and borderline minor impairment from organic loading at the lower two sites (Central Park and Logan). The two lower sites also supported the largest percentage of diatoms that require organic matter in their metabolism and supported diatom associations that were significantly different floristically from diatom associations at the four upstream sites. Aside from these minor impairments and a few teratological (abnormal) diatom cells at each site, the lower Gallatin River exhibited excellent diatom species richness and diversity for a mountain stream.

South Cottonwood Creek had good biological integrity at the upstream and middle sites, but only fair biological integrity at the downstream site above Highway 191. Impairment here was apparently the result of depressed levels of dissolved oxygen, which were caused in turn by multiple factors, including excess inorganic nutrients in the water, respiration in beds of aquatic macrophytes or macroalgae, and low flows with insufficient aeration. A few abnormal diatom cells were observed at all three sites on South Cottonwood Creek, and sedimentation was a minor problem at the middle site. The largest floristic change in the diatom associations of South Cottonwood Creek took place between the upper site and the middle site.

Introduction

This report evaluates the biological integrity¹, support of aquatic life uses, and probable causes of stress or impairment to aquatic communities in South Cottonwood Creek and the lower Gallatin River, based on periphyton samples collected in 2002. The purpose of this report is to provide information that will help the Gallatin Local Water Quality District and the State of Montana determine whether these streams are water-quality limited and in need of TMDLs. This study follows up on a similar study that was based on samples collected in 2001 (Bahls 2002).

The federal Clean Water Act directs states to develop water pollution control plans (Total Maximum Daily Loads or TMDLs) that set limits on pollution loading to water-quality limited waters. Water-quality limited waters are lakes and stream segments that do not meet water-quality standards, that is, that do not fully support their beneficial uses. The Clean Water Act and USEPA regulations require each state to (1) identify waters that are water-quality limited, (2) prioritize and target waters for TMDLs, and (3) develop TMDL plans to attain and maintain water-quality standards for all water-quality limited waters.

Evaluation of aquatic life use support in this report is based on the species composition and structure of periphyton (benthic algae, phytobenthos) communities at 3 sites on South Cottonwood Creek and 6 sites on the lower Gallatin River that were sampled in September 2002. Periphyton is a diverse assortment of simple photosynthetic organisms called algae that live attached to or in close proximity of the stream bottom. Some algae form long filaments or large colonies that are conspicuous to the unaided eye. But most algae, including the ubiquitous and siliceous diatoms, can be seen and identified only with the aid of a microscope. The periphyton community is a basic biological component of all aquatic ecosystems. Periphyton accounts for much of the primary production and biological diversity in Montana streams (Bahls et al. 1992). Plafkin et al. (1989) and Barbour et al. (1999) list several advantages of using periphyton in biological assessments.

¹ *Biological integrity* is defined as “the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region” (Karr and Dudley 1981).

Project Area and Sampling Sites

The project area is located in northern Gallatin County in southwestern Montana. The Gallatin River begins at Gallatin Lake (elevation 9,000 feet) in the northwest corner of Yellowstone National Park. The river then flows NNW for about 80 miles through a narrow, forested canyon and out into the Gallatin Valley near Gallatin Gateway, eventually joining the Missouri River near Three Forks.

The upper sampling site on the Gallatin River (U.S. Highway 191 Bridge) is located at the mouth of the Gallatin Canyon at an elevation of 5,103 feet (Map 1). The lower Gallatin River site (Logan Bridge) is at the opposite end of the Gallatin Valley and below the confluence of the East Gallatin River at an elevation of 4,104 feet (Map 3).

South Cottonwood Creek heads on the slopes of Mount Blackmore (elevation 10,155 feet) in the northern Gallatin Range south of Bozeman. It then flows northwesterly through a forested canyon and out into the Gallatin Valley, joining the Gallatin River near Gallatin Gateway between Williams Bridge and Axtell Bridge. The upper sampling site on South Cottonwood Creek (Map 1) is located at an elevation of 5,800 feet. The lower sampling site (Map 1) is at an elevation of 4,940 feet.

The surface geology of the Gallatin River watershed is complex, consisting mostly of rhyolitic volcanic rocks in the headwaters, assorted limestones, dolomites, sandstones and shales elsewhere in the drainage, and mixed basin fill deposits in the Gallatin Valley (Renfro and Feray 1972). Natural vegetation is alpine tundra at the highest elevations, mixed conifer forest at intermediate elevations, and mixed grassland in the Gallatin Valley (USDA 1976).

The project area is located in the Middle Rockies Ecoregion (upper site on South Cottonwood Creek) and the Montana Valley and Foothill Prairies Ecoregion (Gallatin River and lower South Cottonwood Creek sites) (Woods et al. 1999). The main land uses in the watershed are recreation, livestock grazing, logging, irrigated farming, and residential and commercial development.

Periphyton samples were collected at 6 sites on the Gallatin River and 3 sites on South Cottonwood Creek (Table 1, Maps 1-3). The six sites on the Gallatin River span the length of the Gallatin Valley. The Gallatin Valley is one of the most rapidly growing regions of Montana and much of this growth is occurring along the Gallatin River corridor near Gallatin Gateway, Four Corners (near Shedd's Bridge), and Belgrade.

The lower Gallatin River and South Cottonwood Creek are located in USGS hydrologic unit 10020008 and are classified B-1 in the Montana Surface Water Quality Standards. Waters classified B-1 are suitable for drinking, culinary and food processing purposes, after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply.

Methods

Periphyton samples were collected by GLWQD personnel following standard operating procedures of the MDEQ Planning, Prevention, and Assistance Division. Using appropriate tools, microalgae were scraped, brushed, or sucked from natural substrates in proportion to the importance of those substrates at each study site. Macroalgae were picked by hand in proportion to their abundance at the site. All collections of microalgae and macroalgae were pooled into a common container and preserved with tincture of iodine. Samples were shipped to *Hannaes*, where they were kept cool and in the dark until they were analyzed.

The samples were first examined to estimate the relative abundance and ordinal rank by biovolume of diatoms and genera of soft (non-diatom) algae according to the method described in Bahls (1993). Soft algae were identified using Smith (1950), Prescott (1962, 1978), and John et al. (2002). These books also served as references on the ecology of the soft algae, along with Palmer (1969, 1977).

After the identification of soft algae, a portion of each raw periphyton sample was cleaned of organic matter using sulfuric acid, potassium dichromate, and hydrogen peroxide.

Then, permanent diatom slides were prepared using Naphrax, a high refractive index mounting medium, following *Standard Methods for the Examination of Water and Wastewater* (APHA 1998). Between 408.5 and 477 diatom cells (817 to 954 valves) were counted at random and identified to species. The following were the main taxonomic references for the diatoms: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b. Diatom naming conventions followed those adopted by the Academy of Natural Sciences for USGS NAWQA samples (Morales and Potapova 2000). Van Dam et al. (1994) was the main ecological reference for the diatoms.

The diatom proportional counts were used to generate an array of diatom association metrics. A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1999). Diatoms are particularly useful in generating metrics because there is a wealth of information available in the literature regarding the pollution tolerances and water quality preferences of common species of freshwater diatoms (e.g., Lowe 1974, Beaver 1981, Lange-Bertalot 1996, Van Dam et al. 1994).

Values for selected metrics were compared to biocriteria (numeric thresholds) developed for streams in the Rocky Mountain ecoregions of Montana (Table 2). These criteria are based on metric values measured in least-impaired reference streams (Bahls et al. 1992) and on metric values in streams that are impaired by various sources and causes of pollution (Bahls 1993). The biocriteria in Table 2 are valid only for samples collected during the summer field season (June 21-September 21).

The criteria in Table 2 distinguish among four levels of stress or impairment and three levels of aquatic life use support: (1) no impairment or only minor impairment (full support), (2) moderate impairment (partial support), and (3) severe impairment (nonsupport). These impairment levels correspond to excellent, good, fair, and poor biological integrity, respectively. In cold, high-gradient mountain streams, natural stressors will often mimic the effects of man-caused impairment on some metric values (Bahls et al. 1992).

Quality Assurance

Several steps were taken to assure that the study results are accurate and reproducible.

Upon receipt of the samples, station and sample attribute data were recorded in the Montana Diatom Database and the samples were assigned a unique number, e.g., 2243-02. The first part of this number (2243) designates the sampling site (Gallatin River above Highway 191 Bridge) and the second part (02) designates the number of periphyton samples that have been collected at this site for which data have been entered into the Montana Diatom Database.

Sample observations and analyses of soft (non-diatom) algae were recorded in a lab notebook along with information on the sample label. A portion of the raw sample was used to make duplicate diatom slides. The slide used for the diatom proportional count will be deposited in the Montana Diatom Collection at the University of Montana Herbarium in Missoula. The duplicate slide will be retained by *Hanna* in Helena. Diatom proportional counts have been entered into the Montana Diatom Database.

Results and Discussion

Results for the 2002 samples are presented in Tables 3 and 4, which are located near the end of this report following the references section. Values for key diagnostic metrics (ecological attributes) for both 2001 and 2002 samples are plotted in Figures 1-4, which follow the tables near the end of the report. Field notes by T. Crone (GLWQD) are attached as Appendix A. Appendix B contains a series of diatom reports, one for each sample collected in 2001 and 2002. Each diatom report contains an alphabetical list of diatom species and their percent abundances, and values for 65 different diatom metrics and ecological attributes.

Field Notes (T. Crone)

Microalgae were present at all sites and macroalgae were present at all sites except the lowest site on South Cottonwood Creek (Appendix A). Rock, sediment, and woody debris ranked 1, 2, and 3, respectively, as the most important substrates for algal growth at all sites except the upper site on South Cottonwood Creek, where wood ranked ahead of sediment. Macrophytes were present at the lower two sites on the Gallatin River and at the middle site on South Cottonwood Creek. Mosses were present at the upper site on South Cottonwood Creek.

Sample Notes

South Cottonwood Creek. The sample from the upper site (01) contained moss. *Prasiola* here formed expanded sheets and *Nostoc* was of the species that forms ear-shaped colonies. The sample from the middle site (05) contained mostly *Ranunculus* sp. (water buttercup). *Cocconeis placentula* dominated the diatom assemblage at the lowest site and most of the cells were empty (dead).

Gallatin River. Samples from above U.S. Highway 191 (site 02) and above Williams Bridge (site 03) were silty. *Ranunculus* sp. was present in the latter sample. *Cymbella mexicana* and stalks were common in samples from both of these sites and in samples from the next two sites (06 and 07) downstream, where macroscopic mats of *Oscillatoria* were also present. *Potamogeton* sp. and *Ranunculus* sp. were present in the sample from Logan Bridge (site 13).

Non-Diatom Algae

South Cottonwood Creek. Diatoms, cyanobacteria, and green algae comprised the periphyton community at the upper two sites on South Cottonwood Creek (Table 3). The pollution-sensitive red alga *Audouinella* was also present at the middle site (05). Only diatoms and cyanobacteria were present at the lowest site (06). Diatoms ranked first in biovolume at all three sites. Green algae ranked second in biovolume at site 01 (*Prasiola* sp.) and site 05 (*Cladophora* sp.). A species of *Oscillatoria* ranked second in biovolume at the lowest site (06). The genus *Oscillatoria* includes species that are very tolerant of organic pollution. Sites 01 and 05 supported 11 and 10 genera of non-diatom algae, respectively. Only 3 genera of non-diatom algae were found in the sample collected at site 06 (Table 3).

Gallatin River. Diatoms, cyanobacteria, and green algae were present in samples from all sites on the Gallatin River (Table 3). In addition, the red alga *Audouinella* was found at site 03 and the xanthophytes (yellow-green algae) *Tribonema* and *Vaucheria* were found at site 10. These are common algae in spring habitats and they may indicate an upwelling of cool

groundwater at this site. Diatoms ranked first in biovolume at all sites except 06 and 13, where the filamentous green alga *Cladophora* was most abundant. *Cladophora* ranked second to diatoms at sites 03 and 07. Other important filamentous green algae were *Oedogonium*, *Stigeoclonium*, and *Zygnema*. *Nostoc* and *Tolypothrix*, both pollution-sensitive taxa, were the most common cyanobacteria at the two upstream sites, while *Oscillatoria* and *Phormidium*, both containing pollution-tolerant species, became more common downstream. The number of non-diatom genera at each site ranged from 10 at site 06 to 17 at sites 10 and 13 (Table 3).

Diatoms

Ten of the major diatom species in South Cottonwood Creek and the lower Gallatin River are sensitive to organic pollution and seven are somewhat tolerant of organic pollution (Table 4). None of the major species are very tolerant of organic pollution. *Achnanthes minutissimum* was the most abundant diatom species at the three upstream sites on the Gallatin River and at the uppermost site on South Cottonwood Creek. This is a small, attached (non-motile) species that is adapted to living in fast currents. It is resistant to physical disturbance (scour) and grazing by macroinvertebrates, and tolerates elevated concentrations of heavy metals. It prefers cool water temperatures and low nutrient concentrations, especially low concentrations of inorganic phosphorus. The fact that this species did not exceed 25% abundance at any site indicates low levels of physical, chemical, and biological disturbance in these waters.

Diatom species richness and diversity were excellent at all sites, indicating no significant stresses or perturbations. Although there were at least a few abnormal diatom cells counted at all sites, these may represent natural background mutations rather than chemical toxicity (see McFarland et al. 1997). [Note: Since the report on the 2001 periphyton samples was prepared (Bahls 2002), the threshold for moderate impairment and fair biological integrity has been raised from 1% abnormal cells to 3% abnormal cells (Table 2).]

South Cottonwood Creek. Pollution index values exceeded 2.50 at all sites, indicating no significant organic loading in South Cottonwood Creek (Table 4). Motile diatom species accounted for over 25% of the cells counted at the middle site (05), indicating that sedimentation

was a minor problem here (Table 4). *Cocconeis placentula* accounted for over 50% of the diatom cells at the lowest site (06) on South Cottonwood Creek, indicating moderate impairment and fair biological integrity. This was the only site on either stream to show more than minor impairment. *C. placentula* is a eutraphentic species that requires large concentrations of inorganic nutrients (Van Dam et al. 1994). Excessive loading by inorganic nutrients was evidently a cause of the impairment noted here. Similarity index values for adjacent sites on South Cottonwood Creek show that the largest floristic (and environmental) change occurred between site 01 and site 05 and a somewhat smaller change occurred between sites 05 and 06 (Table 4).

Gallatin River. Diatom species richness and diversity indicated excellent biological integrity at all sites on the lower Gallatin River (Table 4). Values for the pollution index indicated excellent biological integrity at all sites except 10 and 13, where they indicated borderline minor impairment from organic loading. The largest floristic change between adjacent sites occurred between sites 07 and 10; the next largest change occurred between sites 10 and 13. Upstream from site 07, diatom assemblages at adjacent sites were virtually identical. These sites shared more than 70% of their floras. The siltation index indicated minor impairment from sedimentation at all sites on the lower Gallatin. Other than minor sedimentation and a few abnormal cells at all sites, and minor organic loading at sites 10 and 13, the diatoms indicate excellent water quality in the lower Gallatin River.

Diagnostic Metrics

Several diagnostic ecological metrics were extracted from the diatom reports in Appendix B and examined graphically to determine the cause or causes of impairments detected in Table 4. Four metrics were used to evaluate impairment due to (1) high levels of inorganic nutrients (2) excessive loading by organic matter, (3) excessive loading by organic nitrogen, and (4) low levels of dissolved oxygen. Metric data for both 2001 and 2002 are plotted in Figures 1-4.

Inorganic Nutrients. Eutraphentic diatoms (Trophic State Group 5, Van Dam et al. 1994) indicate elevated concentrations of macronutrients that are important for diatom growth: nitrogen, phosphorus, inorganic carbon, and silica. As concentrations of these nutrients increase due to human disturbance, the percentage of eutraphentic diatoms will also increase.

Stations along the lower Gallatin River supported from 30% to 50% eutraphentic diatoms, with no significant changes from site to site (Figure 1). In South Cottonwood Creek, however, the percentage of eutraphentic diatoms increased from about 50% at sites 01 and 05 to almost 80% at site 06. This indicates a significant increase in the concentration of one or more inorganic nutrients at site 06.

Organic Nutrients. Polysaprobous diatoms (Saprobity Groups 4 and 5, Van Dam et al. 1994) characterize waters with heavy loads of organic matter and where oxygen is usually absent or present in small concentrations. The percentage of polysaprobous diatoms will increase as organic loads from human disturbance (e.g., from feedlots and wastewater discharges) increase.

The percentage of polysaprobous diatoms increased markedly at sites 10 and 13 on the lower Gallatin River (Figure 2). This indicates an increase in loading of biodegradable organic matter at these two sites. In South Cottonwood Creek, the percentage of polysaprobous diatoms declined from site 01 to site 05 and again from site 05 to site 06. Percentages of polysaprobous diatoms in South Cottonwood Creek were comparable to percentages at the upstream sites on the lower Gallatin River.

Nitrogen Metabolism. Nitrogen heterotrophs (Nitrogen Metabolism Groups 3 and 4, Van Dam et al. 1994) need elevated concentrations of organically bound nitrogen as a source of energy and nutrients. As concentrations of organic nitrogen increase due to human disturbance, the percentage of nitrogen heterotrophs in the diatom association will also increase.

The percentage of nitrogen heterotrophs followed much the same pattern as the percentage of polysaprobous diatoms (Figure 3), indicating that much of the organic load in these streams is nitrogenous in nature. Terrestrial inputs of organic matter tend to be large in

small headwater streams, thus explaining the relatively large percentage of nitrogen heterotrophs at the upstream site in South Cottonwood Creek. As with polysaprobious diatoms, the percentage of nitrogen heterotrophs was low at the downstream site on South Cottonwood Creek.

Dissolved Oxygen. Diatoms that require high dissolved oxygen (Oxygen Requirements Groups 1 and 2, Van Dam et al. 1994) indicate waters in which dissolved oxygen persists above 75% saturation at all times. A decrease in the abundance of these diatoms may result from organic loading (increased BOD₅) or from diurnal swings in dissolved oxygen caused by plant respiration and low turbulence and aeration due to low gradient and low flows.

Diatoms that require more than 75% saturation of dissolved oxygen accounted for about 50% of the cells at all stations except the middle (05) and lower (06) sites on South Cottonwood Creek (Figure 4). Diatoms that require high dissolved oxygen accounted for about 40% and 25% of the cells at sites 05 and 06, respectively. These sites also support smaller percentages of polysaprobious and heterotrophic diatoms than the upstream site (Figures 2 and 3), indicating that organic loading is not the likely cause of the suppressed dissolved oxygen here. Macroalgae and macrophytes (*Ranunculus* sp.) covered about 35 percent of the stream bottom at the middle site, but no macroalgae or macrophytes were observed at the lower site (Appendix A). Hence, the cause of the lower dissolved oxygen indicated at these sites is likely a combination of low water flows and respiration by large beds of aquatic plants or macroalgae.

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